Cole, Alfred Dodge

Convocation address, August, 1927

Summer Quarter -
Convocation -
August 31, 1927

Address of
Alfred Dodge Cole,
Professor of Physics

s in an Age of Progress

w discoveries, new points of view are cons-
e it is difficult to relate satisfactorily to
get along comfortably by keeping old and new
minds, but of course such a plan makes it
in one's thinking or living. Others say,
anging world - hold fast to any convictions
indeed any abiding values, - things that

as one "Who saw life steadily and saw it
thinker seeks to do. Neither the separate-
nor the disposition to despair of finding
y; an educated man should be able somehow to
new and old, into some sort of a philosophy
of life - like Sophocles "see life steadily and see it whole."

This task of fitting new knowledge and new experience to old, so as to have a consistent whole has never been an easy one, but perhaps it was never so difficult as in this age of rapid change and extraordinary development. It has been especially ~~difficult~~ hard for those of us seeking to keep up with the tremendous changes that have been taking place in modern physics.

The problem is however a general one that every thinking man has to meet. I can perhaps state the difficulty more clearly if I put it in terms familiar to me, citing some of the actual developments the present-day physicist has been compelled to face. I do this the more willingly because these changes are so fundamental that they affect not physics alone, but rather the whole round of the physical sciences, philosophy and the social sciences also. This was clearly indicated a few months

Mental Readjustments in an Age of Progress

In a progressive age new facts, new discoveries, new points of view are constantly being presented, and some of these it is difficult to relate satisfactorily to our previous convictions. Many seem to get along comfortably by keeping old and new ideas in separate compartments of their minds, but of course such a plan makes it impossible to attain any organic unity in one's thinking or living. Others say, how can we - in the midst of an ever-changing world - hold fast to any convictions at all? Have the world and human life indeed any abiding values, - things that remain true from age to age?

Matthew Arnold wrote of Sophocles, as one "Who saw life steadily and saw it whole." And that is what any vigorous thinker seeks to do. Neither the separate-compartment plan for old and new ideas, nor the disposition to despair of finding any real meaning in life is satisfactory; an educated man should be able somehow to integrate his experience, his knowledge new and old, into some sort of a philosophy of life - like Sophocles "see life steadily and see it whole."

This task of fitting new knowledge and new experience to old, so as to have a consistent whole has never been an easy one, but perhaps it was never so difficult as in this age of rapid change and extraordinary development. It has been especially ~~difficult~~ hard for those of us seeking to keep up with the tremendous changes that have been taking place in modern physics.

The problem is however a general one that every thinking man has to meet. I can perhaps state the difficulty more clearly if I put it in terms familiar to me, citing some of the actual developments the present-day physicist has been compelled to face. I do this the more willingly because these changes are so fundamental that they affect not physics alone, but rather the whole round of the physical sciences, philosophy and the social sciences also. This was clearly indicated a few months

ago by the way thoughtful men of many occupations came to the university from all over Ohio to hear Professor Lorentz lecture on the "motion of the earth and the theory of relativity" and to hear Dr. Millikan discuss such topics as the discovery of the electron and the stripping of atoms. Such subjects none but physicists would have shown any interest in ten years ago.

Listen to a famous biologist, J. Arthur Thomson of Scotland: "The new theory of the atom amounts almost to a new conception of the universe. * * The electron theory of matter has thrown a flood of light on what before was hidden. * * It has given us a new conception of the framework of the universe."

Thus the progress of one science helps others; new achievements in physics fire the enthusiasm of a biologist, and I shall presently try to show how a great biological idea has helped physics in a recent crisis in its history.

In the last decade of the 19th. century physicists were in a complacent frame of mind; they felt that the closing century had been one of great achievement. For instance one of the leaders of the science was discoursing in 1894 on these events. He reviewed the verification of the wave theory of light by Young and Fresnel ~~between 1800 and 1835~~ in the first third of the century, the development in the middle of the century of that most fundamental generalization, the conservation of energy. Then he spoke of the establishment of the laws of thermodynamics in the two decades following, and finally of Maxwell's brilliant electromagnetic theory of light and its experimental verification by Hertz just a few years before. Summarizing this complete, well-established and apparently all-inclusive set of laws, the distinguished speaker concluded that all the great discoveries in physics had now been made and future progress was to be looked for, not in finding new phenomena, but in making more exact measurement of those already known.

How different from this prophecy the advances of the past thirty years have proved! The very next year Professor Rontgen presented to the German Physical Society an account of his discovery of X-rays. And the year following that came

something still more startling and altogether new, the discovery of radioactivity. As Dr. Millikan describes this in his Terry lectures at Yale, "Man's view of the nature of this world changed overnight. Matter had heretofore been put up in a definite number * * of eternal, unchangeable chemical elements. In radioactivity we found two of these elements spontaneously shooting off parts of themselves with speeds comparable with the speed of light - speeds which nobody had ever dreamed that matter in any form could attain - and second, by virtue of this process, transforming themselves into new elements." Professor Soddy adds, "The vista opened up by these new discoveries is admittedly without parallel in the whole history of science."

And here is where biology with its long and successful emphasis upon the facts of evolution in organic life, came to the aid of physicists as we wrestled with the new conception of evolving atoms. Quoting J. Arthur Thomson again, "The idea of evolution has influenced all the sciences, forcing us to think of everything as with a history behind it. * * No idea has been so powerful a tool in the fashioning of new knowledge as this simple-but-profound idea, that the present is the child of the past and the parent of the future." We physicists for the first time had to think in terms of dynamic - not static - atoms, components of a universe which is ever changing, living and growing, even in the elements that compose it. And this thought has exerted in recent years a profound influence, not on biology and physics only, but on chemistry, geology, astronomy, and finally on philosophy, the social sciences and religion.

These two new discoveries - X-rays and radioactivity - soon led to other things entirely inexplicable by 19th. century physical theories. It was found for instance that both of the new agencies made common air [redacted] or hydrogen an electrical conductor. Carefuly examination of this phenomenon showed that the atoms of these gases contain some minute electrical constituent which the X-rays are able to dislodge. The era of the indivisible atom — a fundamental idea with chemists for nearly a hundred years, was now a thing of the past, and the era of the study of the constituents

of atoms actively began.

In this study one of the first questions asked and answered was this; how large a fraction of an atom is this electrical constituent of it? Two independent observers in 1897 showed that this minute carrier of electricity has only about $\frac{1}{1800}$ of the mass of the atom of hydrogen, the lightest atom known. So it appeared that electricity as well as matter is atomic in character, but that its atoms are very, very much lighter than those of matter.

Things were happening rapidly and they have kept on happening. About 1901 the mass of an electron was definitely shown to get larger merely by making it move faster. Thus another 19th. centuray fundamental idea - the conservation of mass - appeared to be unsound, for there was a way of actually making mass. Then came Einstein with his relativity formula and showed not only that mass can be transformed into radiant energy, but just how much energy corresponds to a given amount of matter. If this kind of transformation is possible, what becomes of that great idea, whose establishment had been regarded for 50 years as the crowning achievement of the 19th. century, - the conservation of energy? This is a very disturbing thought to physicists, but astronomers have seized upon it eagerly, since it gives them the solution of a problem that they have struggled with for many years without a satisfactory answer - the source of the sun's enormous radiation of energy.

We have already remarked that the atoms in the air can be made to shake off electrons when acted upon by X-rays or the radiations from radium; it was soon discovered that ultra-violet light has a similar power to dislodge electrons from atoms. The close study of this so-called photo-electric effect has led to radical changes in our views regarding the nature of light-radiation. Our classical wave theory of light fails utterly to account for the observed phenomena. On the other hand, the view that light consists of small units called quanta gives a reasonable explanation of the facts observed; ~~On the other hand~~ it is extremely difficult, if not impossible,

to explain by the new quantum hypothesis the numerous and important light effects generally called interference phenomena — such for example as soap bubble colors, the rainbow, the beautiful colored spectra produced by fine-rulings on glass etc. Whereas these things are completely explained by the 19th. century wave theory of light. So we find ourselves today in the unpleasant position of having a large group of new phenomena which our old wave theory will not explain, and yet having to retain the old theory for some things which the new quantum or "light-dart" theory has not been able to explain.

Thus the new phenomena of the sub-atomic world - the physics of the electron - is extremely interesting, but full of puzzles hard to solve. Quoting Millikan's Yale lectures again, "The day has gone by when any physicist thinks he understands the foundations of the universe as we thought we understood them in the nineteenth century. The foregoing discoveries of our generation have taught us a wholesome lesson of humility, wonder and joy in the face of an-as-yet-incomprehensible-physical universe. * * We have learned to work with new satisfaction, new hope and new enthusiasm because there is still so much that we do not understand, because we have found in our life-time more new relations in physics than had come to light in all the preceding ages put together, and because the stream of discovery shows no signs of abatement."

But new emphasis on progressive development through countless centuries of time is not confined to biology and physics. Through careful study of the way rocks lie in the hillsides geologists have found evidences of growth in the earth, through a billion of years at least. The history of terrestrial life, as shown by fossil remains, takes us far back in time but reveals a continuous movement from lower to higher forms of life.

The most impressive of all the recent pictures of an evolving universe, however, are found in recent astronomical advances. Long ago the spectroscope revealed great similarity between our sun and many stars. Matter was shown to be essentially the same everywhere, in earth and sun, in the comet that visits us once in a thousand

years, in the stars billions of miles away from us, and in the clouds of fire-mist that we call nebulae.

Yet the kinds of radiation from millions of stars fall into about a dozen distinct classes or types. Think of a piece of white hot iron, as hot as the blacksmith's forge can make it. In my boyhood I found it a fascinating sight to watch the smith as he hastily beat it into the form he wished; white, then yellow, orange; then red and finally dull and black. So the astronomers pictured the white stars as young, yellow stars older and red stars approaching their end. But recent research shows that there are two kinds of red stars, one kind very old indeed but another kind very young. In the normal life-history of a star, it apprears that it is not so very hot at first, an immense mass of diffuse gas - a socalled "giant star" of dull red color. Betelgeuse is such a star, that bright red star in the shoulder of Orion. This is one of the several fixed stars whose diameters have recently been measured by Professor Michelson of Chicago working with Mr. Pease of the Mt. Wilson observatory. This novel feat was made possible through the use of a special interferometer designed by Professor Michelson and attached to the great 100-inch telescope of the Mt Wilson observatory. It is a fine example of the good results that can come from the joint effort of two specialists in different fields, in this case a great physicist and a skilled astronomer. The result was astounding; Betelgeuse was found to have a volume 4,000,000 times as great as that of our sun, large enough to enclose within itself our whole solar system, ~~even the orbit of distant Neptune~~. On the other hand its density came out only $\frac{1}{400{,}000}$ that of the sun; in other words, it must consists not only of gas, but gas in a highly attenuated form.

According to Professor Russell's theory of giant stars, such a mass of gas will shrink, getting hotter and hotter as it does so, and becoming in turn red, orange, yellow and then white. As soon, however, as it has contracted so far that it no longer obeys the law of a perfect gas, continued shrinkage will produce no higher temperature but rather a cooling. So now the long cycle of changes will be reversed;

the star will become a "dwarf" going through the same list of colors in reverse order as it does so - white, yellow, orange and finally red again. By this time it will have shrunk to a very small fraction of its former size and be relatively a very diminutive dwarf indeed. Our own sun is in the dwarf stage, but its white-yellow color puts it rather early in the dwarf series. Betelgeuse is a child, Vega has reached the noon of life; our sun and Sirius are a little past their prime, while Proxima Centauri is a decrepit old man, with one foot in the grave. For the full rounding out of such a life history of a star, the astronomers calculate that a billion years is none too much.

Here then, in recent astronomical investigations, we have a story of evolutionary development even more striking than biology or the physics-of-the-atom can show. Truly the universe is not a fixed dead thing, but is changing, developing constantly.'

It was inevitable that such radical changes in the physical sciences should react powerfully upon the social sciences, philosophy and even theology. It is very interesting to read something of the impression these discoveries have already made upon philosophers and theologians. Let me quote a few sentences from several prominent thinkers and writers, none of them scientists. Ex-President King of Oberlin says in a recent volume, "Modern science is perhaps the sphere of man's completest success in mastering those great ideal tasks which the mind sets itself - the tasks of thinking the world through into unity in various kinds of terms. Modern Science has succeeded in solving in an unusual degree one of these tasks, that of thinking the world through into unity in mathematico-mechanical terms. And the very fact that men have suceeded at this one point gives hope, as Wm. James suggests, of increasing success in those other parallel tasks which the mind sets itself, of thinking the world through into unity, for example, in esthetic and ethical and religious terms." Again, "It is impossible to overstate the greatness of the opportunity which modern science, in this vision of a new world has given to men with the ideal spirit. ~~It enables us to look forward to a time when a man's life shall be possible for every man.~~ * *. The vision

of such a world means not less than this - the possibility for all men of entering in intelligently and unselfishly into the world life and into the all-embracing plans of God."

President King also calls attention to the great increase that modern science has brought to the power and wealth of civilized nations and shows that this brings a challenge to educational, moral and religious interests, because as he says, " an age pre-eminent in power and wealth must be also pre-eminent in self-control or world disaster impends."

Again Mr. Herbert Croly, editor of the New Republic, writes "Modern Science is using its new knowledge only to increase the control of man over nature and of some men over other men, but some day it will dawn on Christian ministers and on lay evangelists that the new knowledge * * can also be used to increase the control of man over society, and over his behavior, being and destiny." Wm. J ames expresses a similar thought in the following words: "Metaphysics should take heart from the example of physics, * *. Nature may be remodelled, nay certainly will be remodelled, far beyond the point at present reached. Just how far? - is a question which only the whole future history of Science and Philosophy can answer."

An eminent theologian urges the need of ~~creative thinking of~~ "strenously cultivating the scientific spirit and extending the application of the scientific method to the problems of human progress wherever possible." These quotations well illustrate the powerful influence the achievements of modern science are exerting upon thinkers in other fields.

In physiology and medicinethe developments of the past few years have been altogether revolutionary in character. Take for instance the progress in the study of heredity along the lines of Mendel's epoch-making experiments or the work of Starling and Bayliss on the functions of the hormones, those chemical messengers of the ductless glands, in establishing that harmony of bodily functions which we know as health. The report of the Rockefeller Foundation for 1926 is just out. This

great institution is spending nearly $10,000,000 a year for medical education and for a great program of public health that extends into twelve countries. This report recounts the triumphs of preventive medicine. In recent years infant mortality in London and New York has been reduced more than one half; small-pox is almost unknown in parts of Europe and in some states of this country; tuberculosis is decreasing; diptheria is coming under successful control and so are the activities of the malaria-carrying mosquito.

If we had time at our disposal we might consider all the different fields of knowledge and show how in all of them rapid changes are being made, - so rapid that we need continually to readjust our point of view and fit new knowledge to old.

How can such readjustments be made? In the first place we note that new discoveries often turn out to be less revolutionary than they at first appear to be. Take the changes we noted in the field of physics for instance. We saw that most of the great principles established in the nineteenth century, such as the indistructibility of chemical elements, the conservation of matter, the conservation of energy and the wave theory of light, now need some modification, but it is important to notice that they still hold valuable truth for us.

The number of radioactive elements is small and they constitute but an insignificant portion of the earth's crust. The portion of radioactive matter that anyone of us has been in contact with during life is doubtless far less than 1 part in a million of all the matter we have dealt with. When this country undertook, a few years ago to give Madame Curie a thirtieth of an ounce of radium, it proved an expensive and a memorable undertaking to collect it.

The ninety-two elements of chemistry are still and doubtless always will be the ultimate units of chemical combination, even if they are now shown to be built up of electrons and protons. We have had to reconstruct our old views a bit, but not abandon them; it is astonishing how seldom a carefully constructed theory has to be given up.

Nor is the principle of the conservation of mass ready for the scrap heap. Nothing on earth is known to change mass except a few electrons inside special tubes and under the driving power of extraordinary voltages. And Einstein's change of mass into energy can not take place at all on this earth for it requires temperatures far higher than we ever have here. It can happen only in such locations as the central core of the sun or distant stars; it cannot come within the actual experience of any one of us. Similarly with the laws of electro-dynamics; 99% of our electrical engineering is done with our nineteenth-century ideas and methods; in connection with only a very few novelties like television do we have to call in the new quantum theory to help us. In a word, nineteenth-century physics is for the most part eternal truth, and what is true of physics is probably true of most departments of knowledge. Sciences grow mainly by minute additions and most discoveries are modifications and extensions of others preceding them.

But since it is also true that there are things absolutely new coming into our experience - things like radioactivity and the electron in physics - we must expect that some mental readjustments will be necessary to unite the new knowledge to the old without losing truth in either. We must recognize clearly that we are part of an ever-growing, developing world, and must grow with our world. We must keep an attitude of attention to the new things that are appearing, at the same time keeping fast hold of tried and tested things; even when it is hard to see how both can be true. And sometimes it may happen that our first attempt to unite the new and old will not be entirely successful and we must patiently try again.

For example, the past few years have made it necessary for us to reconsider from a new angle a mental adjustment that some of us made decades ago. We have witnessed a strange revival of a conflict that raged 50 years ago, - the struggle of a certain interpretation of religion against organic evolution. At this time as many times before in human history, the Bible is being appealed to, to decide a purely scientific

question.

Let us glance briefly at some of the historic examples of this. In the 15th. century Columbus argued in favor of the Arabian astronomers' idea that the earth is spherical, but a Council of the Church in Spain condemned his opinion as contrary to the scriptures. His voyage to America proved him right.

A generation later the astronomer Copernicus wrote a book to prove that the earth revolves around the sun. The Inquisition promptly condemned the book and forbade its circulation on the ground that it was "utterly contrary to the Holy scriptures." But nevertheless his idea has become universally accepted.

Seventy years later the same thing occurred with reference to the discoveries which Galileo made with his newly-devised telescope. So bitter were his opponents that his last ten years were spent in prison. Yet all of his discoveries were soon accepted everywhere as correct.

So later Newton's gravitation law and the testimony of the rocks to the great age of the earth have been unseccessfully attacked as contrary to the Bible.

All five of these notable attempts to judge a conclusion of science by appeal to the scriptures met with humiliating defeat. Yet when the discussion of evolution came fifty years ago the same methods were used once more. However after long debate peace came, and the rank and file of biologists - as well as their leaders-- had learned to reconcile Christian faith and their belief in evolution.

And now in these past few years we have been astounded to see what Conklin calls "a curious recrudensce of the old theological fight against evolution." Strangest of all, in this twentieth century, is the attempt by these modern exponents of the Inquisition spirit to force upon all of us their own interpretation of Scripture through legislative enactment - by the passage of state laws against the teaching of evolution in schools and colleges. Indeed national legislation of the same sort is a part of their plan. Such intolerance and bigotry all educated and thoughtful men should

strenously oppose. And those of us who are interested in the work of the Christian church ought to protest against such misuse of the Bible; we have no reason to believe that it was ever intended to solve questions in geography, astronomy, geology, physics or biology. Such questions must be answered through the application of scientific method by men who are trained in the use of such methods. And the evolution of organic life is such a question.

It should not disturb any of us if it should sometimes seem necessary to re-adjust our standards of conduct and our interpretations of religious ideas. The Bible itself tells a story of change and progress in men's conception of God and their own obligations. David's ideas of God and duty were better than those of Jacob, and John the apostle was far in advance of David. Christ's concepts and ideals were so far in advance of those set forth in the old testament that we rightly say he established a new order or dispensation. It is not too much to say that the Bible gives us in itself an excellent example of evolutionary development.

We are apt to think of our pilgrim ancestors at Plymouth as narrow and intolerant, but on the wall of the old first church of Plymouth one may read this quotation from John Robinson, their pastor when the Mayflower sailed: "There is more Truth and Light yet to come from God's holy word." It would seem that the spiritual guide of the Plymouth colony was more open-minded toward new interpretations of truth than some modern church members are.

What message can I leave with you who are graduating-from-the-university today? You will be taking your places of responsibility and leadership in various communities all over this great state and beyond. You will be called upon to take a leading part in the solution of community problems. Your friends and acquaintances will come to you with their personal difficulties. During your period of study you have learned to make some mental readjustments, but you will need to make still others if you succeed in taking and keeping the position of leadership to which your training entitles you.

The idea of progress, of our participation in it and responsibility for it, is now well established in the popular mind. You may not believe with me that the modern achievements of Science have had a large part in establishing this expectation of progress in every line of human activity, but we all recognize that the idea is widespread and this is a fact of profound significance. It is largely responsible for the optimistic outlook on life that is so characteristic of our American communities. It has been true of some Oriental peoples that they feel themselves in the grip of an all-embracing fate which paralyzes effort; our people aspire to an understanding of the mechanism of the universe that will give them a key to the mastery of its forces. This idea of progressive development permeates every phase of modern life, and so too does the idea of service and social betterment. We recognize that we live for the good that we may do, and these ideals are finding expression in many varieties of reform and welfare work. Slowly but surely they are modifying industrial and business standards. And we, as educated men and women, have a duty and a responsibility in seeing that this optimistic and altruistic outlook is extended everywhere until it becomes universal. The whole process of which we are a part is a slow, but a continuing growth, and one of the chief advantages of a college education is that it enables one to estimate more correctly his own place in this ever-expanding development. With increasing knowledge we come to appreciate that we occupy a world of order and of beauty that goes with order - a world whose activities we can understand and in an increasing degree predict, a world finally that has within it forces which can be counted upon to operate for the enrichment of human life and happiness, just so soon as we learn to understand them and to work in harmony with them.